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Systematic Studies on the Conducting Tissue of the Gametophyte in Musci

(12) Anatomical Characteristics of Stems in Some Species of Bartramiaceae

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Abstract In the ten species of Bartramiaceae, the cross and the longitudinal sections of the stem are observed, and from what SLOOVER and MATTERI stated, the species of Bartramiaceae are classified into five groups. The stems of ten species of Bartramiaceae show the same typs regarding some of the anatomical characteristics in the cross and the longitudinal sections (**IV-N-I-Q-HSI-ERE** type). Of the anatomical characteristics of longitudinal and cross sections hitherto observed, these characteristics; type of inner differentiation of the stem (**III** and **IV** types), comparison of the size of cells (**M** and **N** types), comparative thickness of cell walls in the hadrom (**P** and **Q** types), thickness of cell walls in the hadrom (**R** and **S** types), comparative length of cells in the hadrom (**H3A**, **H4A** and etc. types), among which some regularity has been observed also in the stem of Amblystegiaceae, Dicranaceae, Leucobryaceae and Bartramiaceae, appear to be important in making an investigation of the essential characteristics.

Introduction

Many of the anatomical characteristics hitherto observed, which are closely connected with the cutting at the early-stage of the ontogeny, seem to indicate a certain regularity. For making an analysis of the organization of the stem in Musci, we must gain a better understanding of the process of development in the gametophyte. That is, we must to investigate what mode of division goes on in three series of segments, Segment **I**, Segment **II** and Segnent **III**, which have been cut off from apex of the stem (**DGS**-type). The initial of the epidermis and the cortex seems to originate from the two middle cells (**AII**-cells) which are derived from segments through the mode of division of **PGS** type. The initial of the leptom and the hadrom seems to originate from the one inner cell (**B**-cell) which comes from a segment.

In the fresh stem of *Bartramia pomiformis* HEDW. chloroplasts are found in the cell of the epidermis, cortex and the leptom of young stem, but is not in the hadrom. And in the old stem chloroplasts are only found in the cell of the cortex (Fig. 1 and 2). The stem of

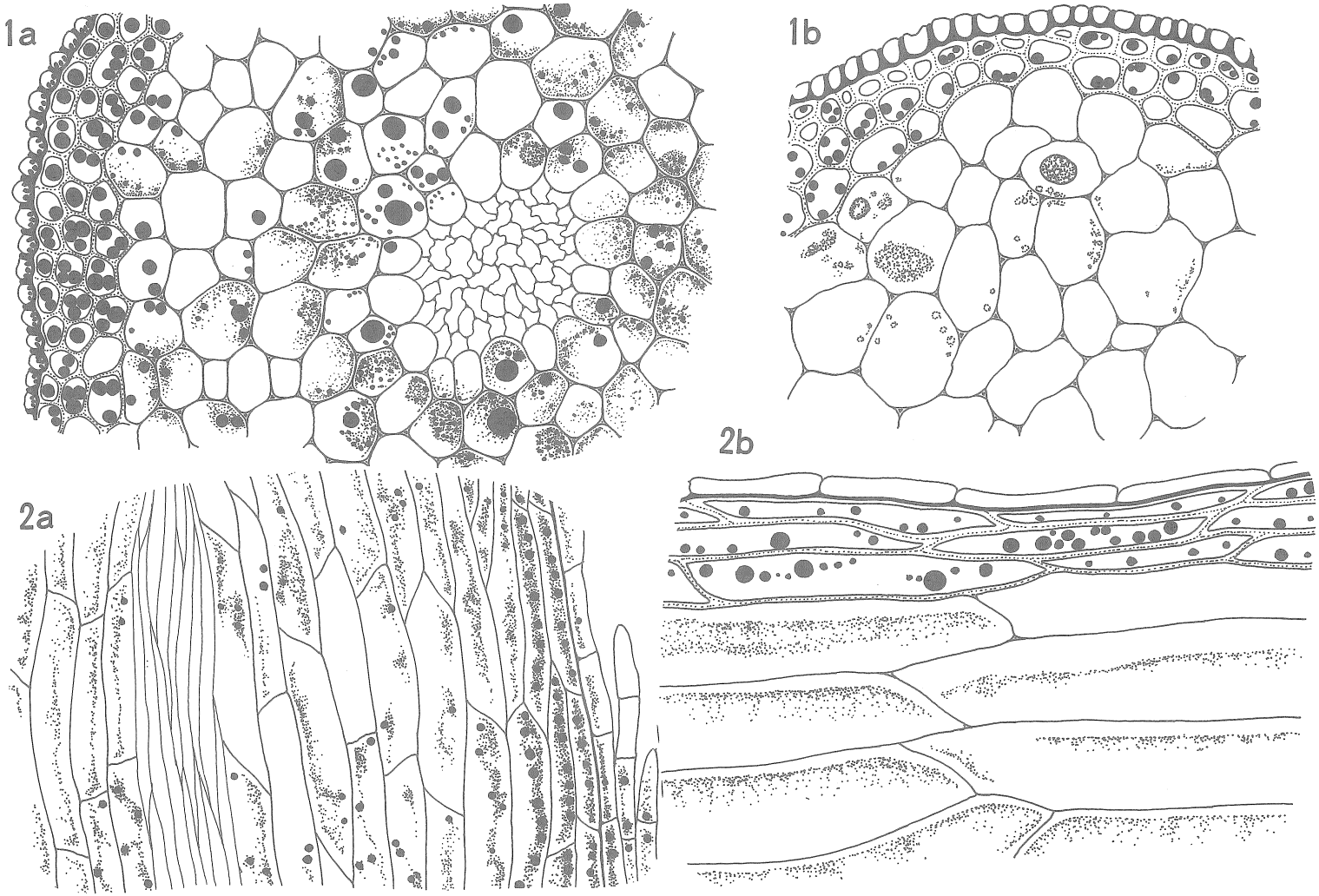

Fig. 1-2 *Bartramia pomiformis* Hedw. x 400
Cross sections (Fig. 1) and longitudinal sections (Fig. 2) of the fresch stem
a : The young stem, b : The old stem

Bartramia pomiformis HEDW. seems to consist of an epidermis, cortex, leptom, hydrom sheath and a hadrom (IV-type). We wish to make further research into the matter pertaining to what sort of feature is the essential characteristic.

Materials and Methods

The materials used for this research are composed of specimens of mosses collected in Japan. All the samples studied are deposited in the Moss Herbarium of Kanazawa University.

Bartramia pomiformis HEDW.: Ishikawa (32633), Nagano (32677), *Bartramia pomiformis* HEDW. var. *elongata* TURN.: Miyazaki (32517), Miyagi (34916), *Breutelia arundinifolia* (DUB.) FL.: Kagoshima (37389), Kagoshima (35079), *Fleischerobryum longicolle* (HAMP.) LOESK.: Wakayama (37359), *Philonotis falcata* MITT.: Toyama (32632), Hyoogo (39159), Niigata (39366), Ehime (35081), *Philonotis fontana* (HEDW.) BRID.: Nagano (37511), Nagano (35040), *Philonotis revoluta* BOSCH. et LAC.: Miyazaki (39406), Kumamoto (35060), *Philonotis socia* MITT.: Kumamoto (34994), *Philonotis thwaitesii* MITT.: Ehime (39399), *Philonotis turneriana* (SCHWAEGR.) MITT.: Aomori (35077), Miyazaki (39405), Kumamoto (35024), Kumamoto (37510).

The hard mosses are boiled in water for about an hour in order to prevent the soft tissue from breaking. The inner structure of the stem is studied from transverse sections and longitudinal sections having a thickness of five microns. Gentian violet, acid fuchsin and potassium iodide iodine are used staining anatomical preparations.

Observation and Discussion

In the ten species of Bartramiaceae, the cross and the longitudinal sections of the stem are observed.

(1) Anatomical Characteristics in the Cross Sections of the Stem

The affinity regarding the anatomical characteristics of stem cross section in Bartramiaceae is considered (Plate I-V, Tab. 1). From what SLOOVER (1975) and MATTERI (1968, 1973) stated, the species of Bartramiaceae are classified into five groups (Tab. 1). Namely, the species of this family are divided into the group of **R**-type and of **S**-type in the hadrom. The group of **R**-type is divided into the group of **V**-type and of **W**-type in the epidermal cells. The group of **S**-type is divided into the group of **Q**-, **P**-and **O**-types in the cell walls of hadrom.

The relationship between the affinity regarding the anatomical characteristics and the classification is discussed (Tab. 2).

Tab. 1 Affinity regarding the anatomical characteristics in the cross section of the stem in twenty-two species of Bartramiaceae

	Number of the cell layers of the leptom is 1-4 cell layers (A type) or 4-13 cell layers (B type)	Number of the cell layers of the cortex is 1-4 cell layers (C type) or 4-7 cell layers (D type)	Cells of the epidermal layer are hyalodermal (T type) or not (U type)	Cells of the epidermal layer are larger (V type), as large (W type) or smaller (X type) than those of the cortex	Cell walls of the hadrom are thicker (O type), as thick (P type) or thinner (Q type) than those of the leptom	Cells of the hadrom are parenchymatous (R type) or not (S type)	Epidermal cell walls are thicker (G type), as thick (H type) or thinner (I type) than those of the cortex	Cells of the hadrom are larger (L type), as large (M type) or smaller (N type) than those of the leptom	The stem differentiates into an epidermis, cortex, leptom and a hadrom (III type) or into an epidermis, cortex, leptom, hydrom sheath and a hadrom (IV type)	Number of the figures in the Plate or authors
Fleischerobryum longicolle (HAMP.) LOESK.	A	C	T	V	Q	R	I	N	IV	I-1
Philonotis fontana (HEDW.) BRID.	A	C	T	V	Q	R	I	N	IV	I-2
Philonotis revoluta BOSCH. et LAC.	A	C	T	V	Q	R	I	N	IV	II-1
Philonotis turneriana (SCHWAEGR.) MITT.	A	C	T	V	Q	R	I	N	IV	II-2
Philonotis falcata MITT.	A	C	T	V	Q	R	I	N	IV	III-1
Philonotis socia MITT.	A	C	T(U)	V	Q	R	I	N	IV	III-2
Philonotis thwaitesii MITT.	A	C	T(U)	V	Q	R	I	N	IV	IV-1
Bartramia pomiformis HEDW.	A	C	T(U)	W	Q	R	I	N	IV	V-1
Bartramia pomiformis var. *elongata* TURN.	B	C	T(U)	W	Q	R	I	N	IV	IV-2
Breutelia stenodictyon (REN. et CARD.) BROTH.	A	C	U	V	Q	S(R)	I	N	IV	SLOOVER
Breutelia arundinifolia (DUB.) FI.	B	D	T	V	Q	S(R)	I	N	IV	V-2
Breutelia stricticaulis DIX.	B	D	T	V	Q	S(R)	I	N	IV	SLOOVER
Breutelia perrieri THÉR.	A	C	T	V	Q	S(R)	I	N	IV	SLOOVER
Breutelia viquieri CARD.	B	D	T	V	P	S(R)	I	N	IV	SLOOVER
Breutelia muhavurensis VARD. et THÉR.	A	D	T	V	P	S(R)	I	N	IV	SLOOVER
Breutelia gnaphalea (P. BEAUV.) MITT.	B	D	T	V	P	S(R)	I	N	IV	SLOOVER
Breutelia stuhlmannii BROTH.	B	D	T	V	O	S	I	N	IV	SLOOVER
Breutelia diffracta MITT.	B	D	T	V	O	S	I	N	IV	SLOOVER
Breutelia magdalenae SLOOV.	B	D	T	V	O	S	I	N	IV	SLOOVER
Breutelia sciuroides THÉR.	B	C	T	V	O	S	I	N	IV	SLOOVER
Breutelia humbertii VARD. et THÉR.	B	D	T	V	O	S	I	N	IV	SLOOVER
Breutelia borbonica SLOOV.	B	D	T	V	O	S	I	N	IV	SLOOVER

Tab. 2 Relationship between the affinity regarding the anatomical characteristics and the classification

Fleischerobryum	IV-N-I-R-Q-V
Philonotis	IV-N-I-R-Q-V
Bartramia	IV-N-I-R-Q-W
Breutelia	IV-N-I-S(R)-Q-V IV-N-I-S(R)-P-V IV-N-I-S-O-V

From the table, the stem of the species belonging to the identical genus shows similar anatomical characteristics, except the genus *Breutelia*. Of the anatomical characteristics, the five characteristics (**IV**-, **N**-, **I**-, **R.S**- and **O.P.Q**-types) may be of great importance to the classification system.

(2) Anatomical Characteristics in the Longitudinal Sections of the Stem

The stems of Bartramiaceae are classified into five types through an observation of the cross section. As a result of longitudinal observing the ten characteristics as in Table 3 are considered.

The cell-length of the epidermis is represented by the sign "A", and the cell-length of each tissue is shown as the ratio to that of the epidermis. The shape of the cell is itemized into three types, rectangular, rhombic and spindle. The thickness of the septum is shown as ratio to that of the cell walls.

In the species of all genera the septum of the hadrom is as thick as the vertical cell walls of the hadrom (**HSI** type) and the all species have with rectangular epidermis (**ERE** type). In *Philonotis socia* MITT. and *Philonotis fontana* (HEDW.) BRID., the cell-length of the hadrom is more than four times the length of the epidermal cells (**H4A** type), in *Bartramia pomiformis* HEDW. and *Bartramia pomiformis* var. *elongata* TURN., longer than 3A, and in *Breutelia arundinifolia* (DUB.) FL., *Philonotis falcata* MITT., *Philonotis turneriana* (SCHWAEGR.) MITT., *Philonotis revoluta* BOSCH. et LAC. and *Philonotis thwaitesii* MITT., longer than 2A and *Fleischerobryum longicolle* (HAMP.) LOESK., as long as the epidermal cells (**HA** type). In *Philonotis revoluta* BOSCH. et LAC. and *Philonotis thwaitesii* MITT. the cell-length of the cortex is twice the length of the epidermal cells (**C2A** type) and in the other species the cortex is **CA** type.

(3) Affinity Regarding the Anatomical Characteristics Seen in the Cross and Longitudinal Sections

The stem of ten species of Bartramiaceae show the same types regarding some of the anatomical characteristics in the cross and longitudinal sections (**IV-N-I-Q-HSI-ERE** type). The stem of *Breutelia arundinifolia* (DUB.) FL. has the hadrom of **S** type, but the stems of the nine species other than *Breutelia arundinifolia* are of the type that the cell walls of the parenchymatous hadrom (**R** type)are thinner than those of the leptom (**Q** type), and that the cells of epidermal layer are hyalodermal (**T** type). In the two species of *Bartramia* the cells of epidermal layer are as large as those of the cortex (**W** type), but in

Tab. 3 Observation of the anatomical characteristics in the longitudinal section of the stem in ten species of Bartramiaceae

Species	Length of cell ($_A$: Length of cell in the epidermis)			Shape of cell				Thickness of the septum (Comparison with the longitudinal cell walls)		
	Cortex	Leptom	Hadrom	Epidermis	Cortex	Leptom	Hadrom	Cortex	Leptom	Hadrom
Fleischerobryum longicolle (HAMP.) LOESK.	C_A	L_{2A}	H_A	E_{RE}	$C_{RE(RH)}$	$L_{RE(RH)}$	H_{SP}	C_{TN}	L_{TN}	H_{SI}
Philonotis fontana (HEDW.) BRID.	C_A	L_{2A}	H_{4A}	E_{RE}	C_{RH}	L_{RE}	H_{SP}	C_{SI}	L_{TN}	H_{SI}
Philonotis revoluta BOSCH. et LAC.	C_{2A}	L_{2A}	H_{2A}	E_{RE}	C_{RE}	L_{RE}	H_{RH}	$C_{SI(TN)}$	L_{SI}	H_{SI}
Philonotis turneriana (SCHWAEGR.) MITT.	C_A	L_A	H_{2A}	E_{RE}	C_{RH}	$L_{RH(RE)}$	H_{SP}	C_{TN}	L_{TN}	H_{SI}
Philonotis falcata MITT.	C_A	L_A	H_{2A}	E_{RE}	C_{RH}	L_{RE}	H_{SP}	C_{SI}	L_{TN}	H_{SI}
Philonotis socia MITT.	C_A	L_{2A}	H_{4A}	$E_{RE(RH)}$	C_{RH}	L_{RE}	H_{SP}	C_{TN}	L_{TN}	H_{SI}
Philonotis thwaitesii MITT.	C_{2A}	L_{2A}	H_{2A}	E_{RE}	C_{RE}	L_{RE}	H_{SP}	C_{SI}	L_{SI}	H_{SI}
Bartramia pomiformis HEDW.	C_A	L_{2A}	H_{3A}	E_{RE}	C_{RH}	L_{RE}	H_{RH}	C_{SI}	L_{SI}	H_{SI}
Bartramia pomiformis var. elonpata TURN.	C_A	L_{2A}	H_{3A}	E_{RE}	C_{RH}	L_{RE}	H_{SP}	C_{SI}	L_{TN}	H_{SI}
Breutelia arundinifolia (DUB.) FL.	C_A	L_{2A}	H_{2A}	E_{RE}	C_{RH}	L_{RE}	$H_{SP(RH)}$	C_{SI}	L_{TN}	H_{SI}

C: Cortex, L: Leptom, H: Hadrom, E: Epidermis, ^{RE}: Rectangular, ^{RH}: Rhombic, ^{SI}: The septum is as thick as the longitudinal cell walls, ^{TN}: The septum is thinner than the longitudinal cell walls

Tab. 4 Affinity regarding the anatomical characteristics in the cross and longitudinal sections of the stem

Fleischerobryum longicolle (HAMP.) LOESK.	C_A	H_{SP}	H_A	V	T	Q	R	E_{RE}	I	H_{SI}	N	IV
Philonotis falcata MITT.	C_A	H_{SP}	H_{2A}	V	T	Q	R	E_{RE}	I	H_{SI}	N	IV
Philonotis turneriana (SCHWAEGR.) MITT.	C_A	H_{SP}	H_{2A}	V	T	Q	R	E_{RE}	I	H_{SI}	N	IV
Philonotis thwaitesii MITT.	C_{2A}	H_{SP}	H_{2A}	V	T	Q	R	E_{RE}	I	H_{SI}	N	IV
Philonotis revoluta BOSCH. et LAC.	C_{2A}	H_{RH}	H_{2A}	V	T	Q	R	E_{RE}	I	H_{SI}	N	IV
Philonotis socia MITT.	C_A	H_{SP}	H_{4A}	V	T	Q	R	E_{RE}	I	H_{SI}	N	IV
Philonotis fontana (HEDW.) BRID.	C_A	H_{SP}	H_{4A}	V	T	Q	R	E_{RE}	I	H_{SI}	N	IV
Bartramia pomiformis HEDW.	C_A	H_{RH}	H_{3A}	W	T(U)	Q	R	E_{RE}	I	H_{SI}	N	IV
Bartramia pomiformis var. *elongata* TURN.	C_A	H_{SP}	H_{3A}	W	T(U)	Q	R	E_{RE}	I	H_{SI}	N	IV
Breutelia arundinifolia (DUB.) FL.	C_A	$H_{SP(RH)}$	H_{2A}	V	T	Q	S(R)	E_{RE}	I	H_{SI}	N	IV

IV : The stem differentiates into an epidermis, cortex, leptom, hydrom sheath and a hadrom

N : Cells of the hadrom are smaller than those of the leptom

I : Epidermal cell walls are thinner than those of the cortex

H_{SI} : Thickness of the septum is as thick as the longitudinal cell walls

E_{RE} : Shape of the epidermal cells is rectangular

R : Cell walls of the hadrom are parenchymatous

Q : Cell walls of the hadrom are thinner those of the leptom

T : Cells of the epidermal layer are hyalodermal

V : Cells of the epidermal layer are larger than those of the cortex

S : Cells of the hadrom are not parenchymatous

U : Cells of the epidermal layer are not hyalodermal

W : Cells of the epidermal layer are as large as those of the cortex

H_A : Length of cell in the hadrom is as long as in the epidermis

H_{2A} : Length of cell in the hadrom is twis in the epidermis

H_{3A} : Length of Cell in the hadrom is three times in the epidermis

H_{SP} : Shape of cell in the hadrom is spindle,

H_{RH} : Shape of cell in the hadrom is rhombic

the species of genera *Fleischerobryum* and *Philonotis* the cells of epidermal layer are larger than those of the cortex (Tab. 4).

Among the stems of **IV-N-I-R-Q-T-V-HA** type is included *Fleischerobryum longicolle* whose stem has the cortex of **CA** type and the leptom of **L2A** type. Of the stems with the **IV-N-I-R-Q-T-V**-type, the stems with the hadrom of **H2A** type are found in *Philonotis falcata, Philonotis turneriana, Philonotis revoluta* and *Philonotis thwaitesii,* and the stems with the hadrom of **H4A** type are found *Philonotis socia* and *Philonotis fontana.*

Of the anatomical characteristics of longitudinal and cross sections hitherto observed, the following characteristics are selected ; type of inner differentiation of the stem (**III** and **IV** types), comparison of the size of cells (**M** and **N** types), comparative thickness of cell walls in the hadrom (**P** and **Q** types), thickness of cell walls in the hadrom (**R** and **S** types), comparative length of cells in the hadrom (**H3A, H4A** and etc. types). These characteristics, among which some regularity has been observed also in the stems of Amblystegiaceae, Dicranaceae, Leucobryaceae and Bartramiaceae, appear to be important in making an investigation of the essential characteristics.

Amblystegiaceae : **III-HSI-HSP-H4A-M(N)-P(Q)-S-U-C**
Leucobryaceae : **III (IV)-Q-R(S)-HSI**
Dicranaceae : **IV-H4A-HSI-N(M)-HSP-Q(P)**
Bartramiaceae : **IV-N-Q-I-HSI-ERE-R(S)-T(U)-V(W)**

We wish to make further research into the matter pertaining to what sort of feature is the essential characteristic after this.

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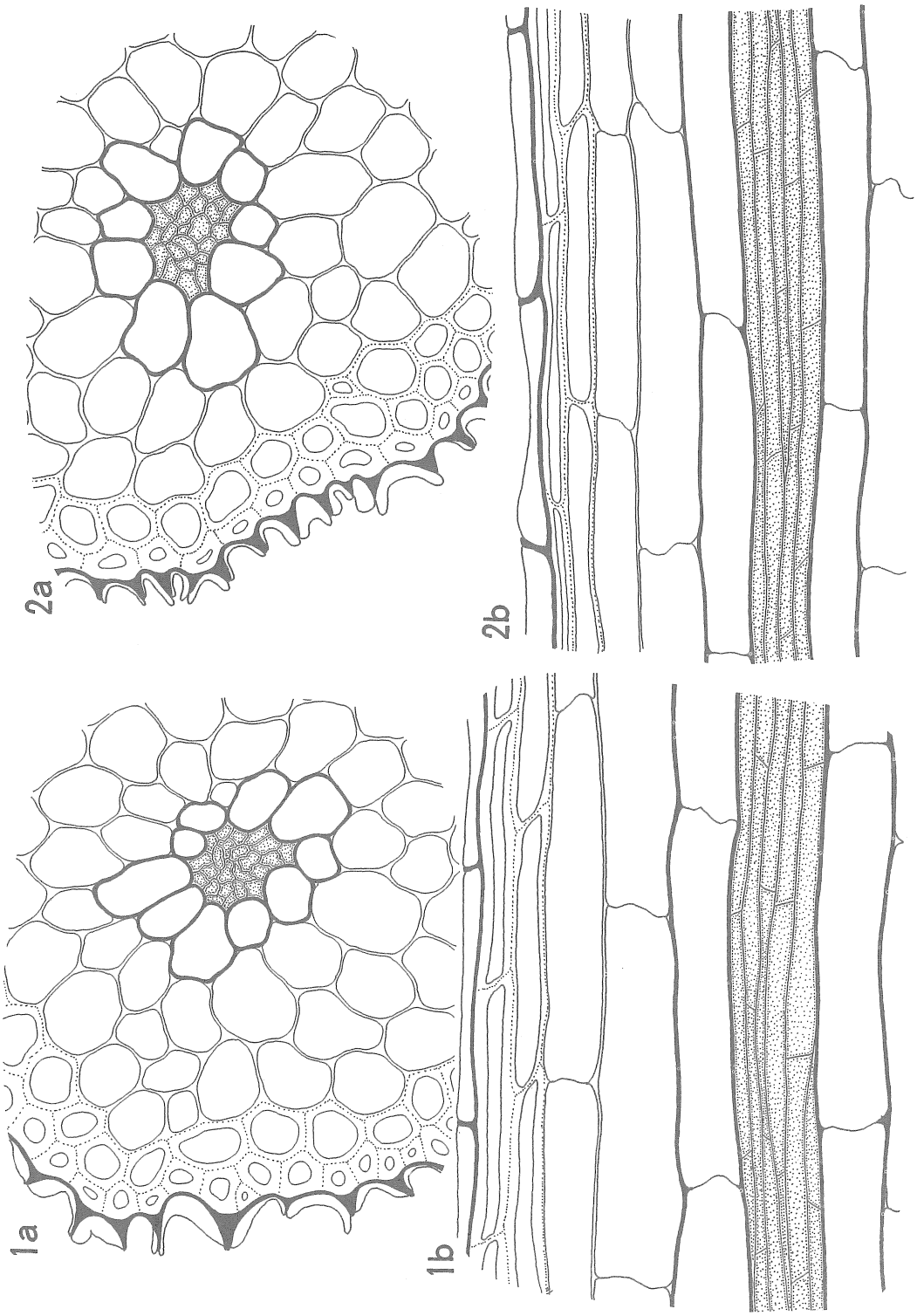
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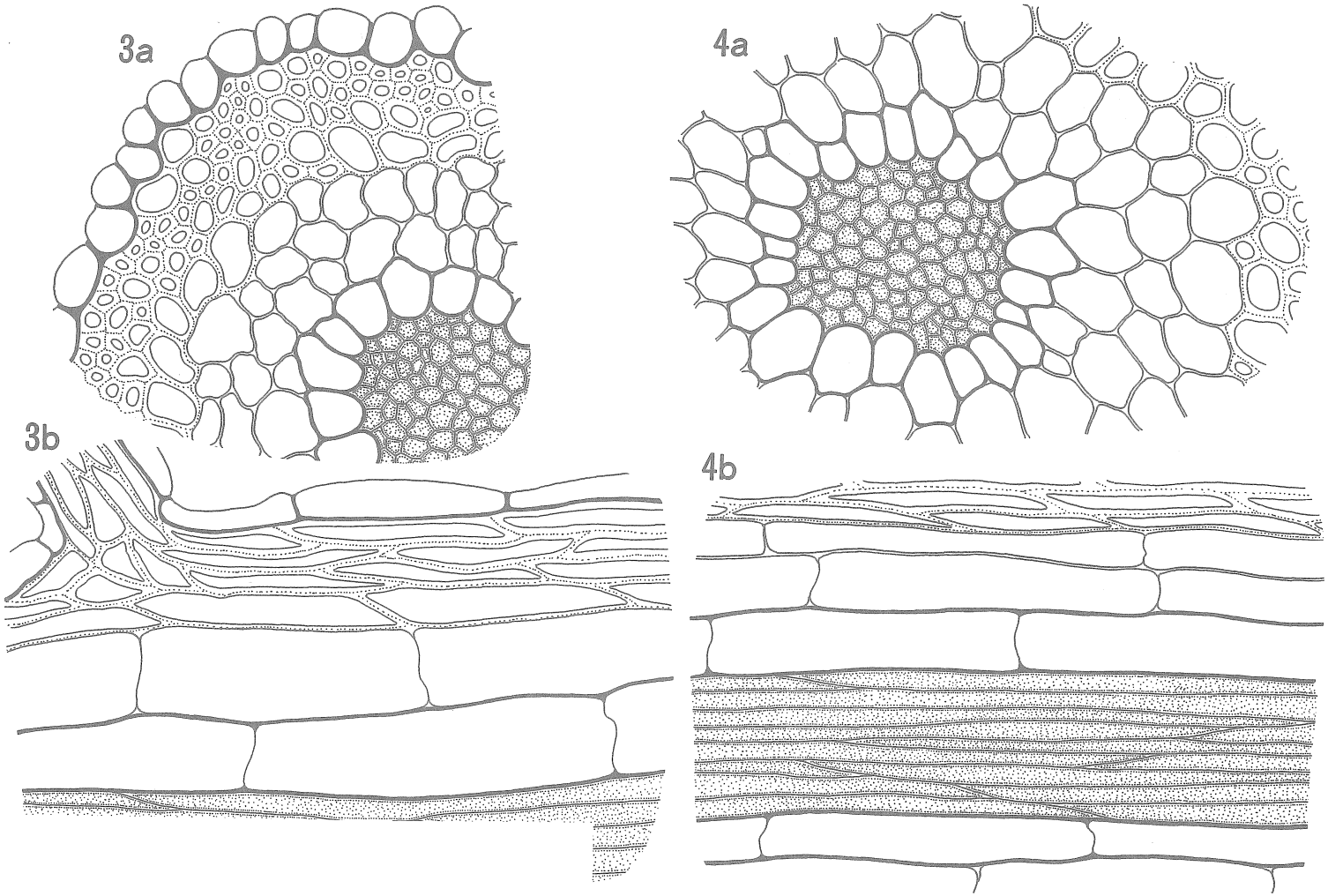
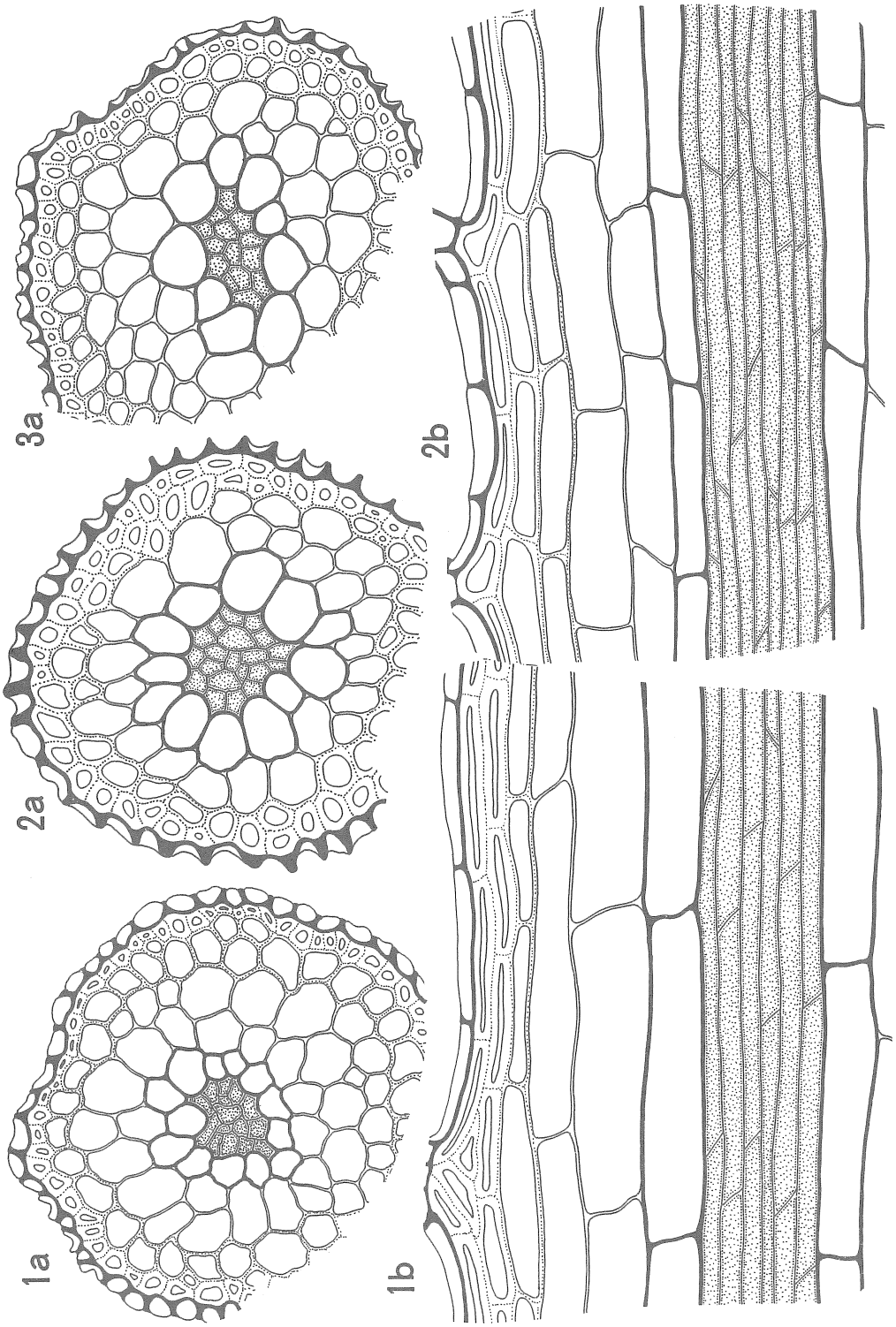


Plate I Cross and longitudinal sections of the stem
1-2 : *Fleischerobryum longicolle* (Hamp.) Loesk. x 300
3-4 : *Philonotis fontana* (Hedw.) Brid. x 300
a : Cross sections, b : Longitudinal sections


3a
2b
2a
1a
1b

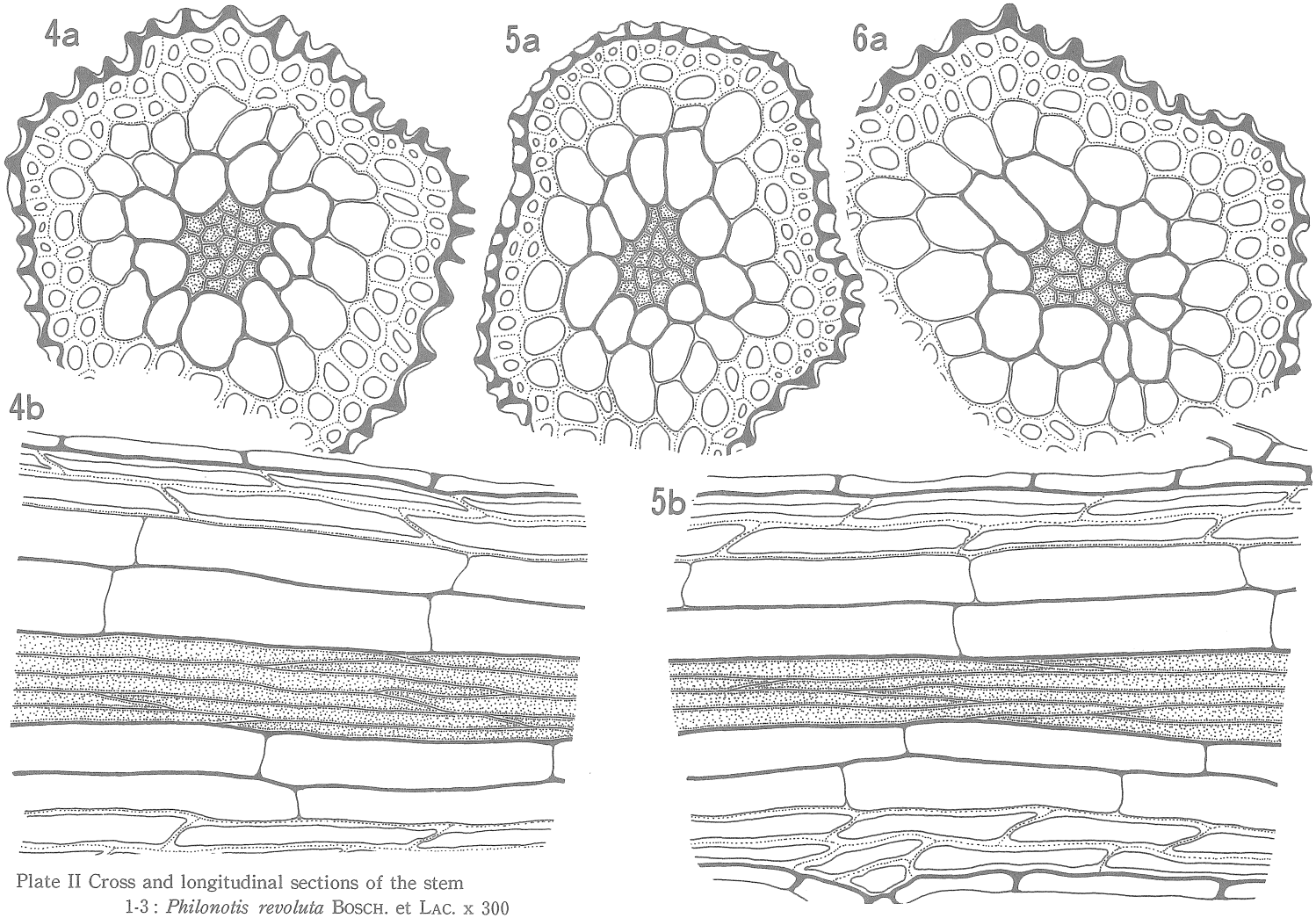
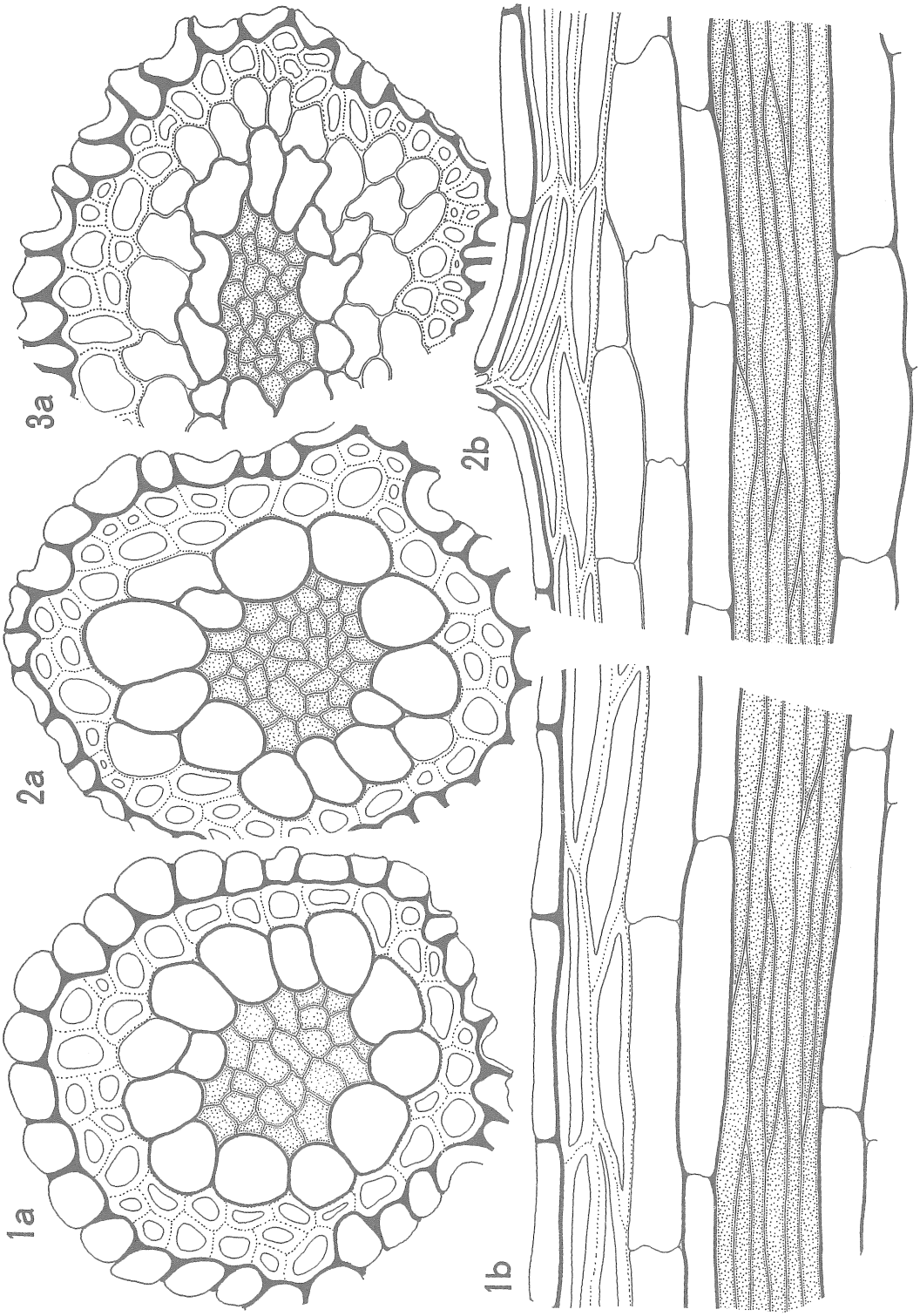
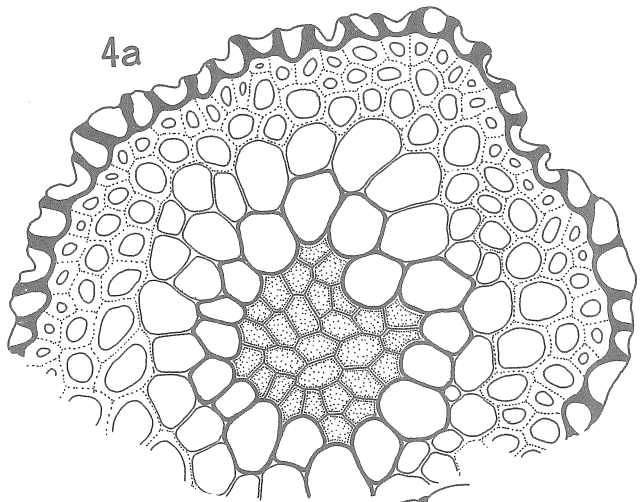
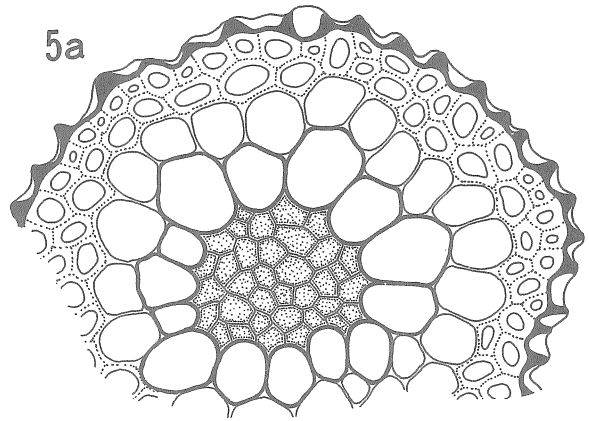
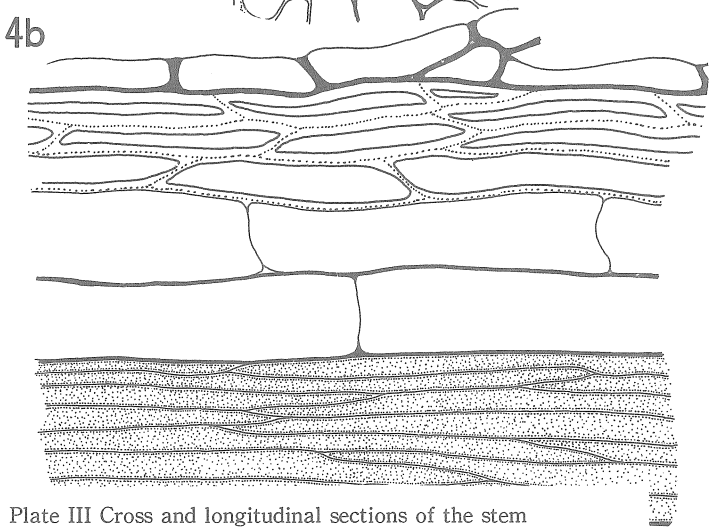


Plate II Cross and longitudinal sections of the stem
1-3 : *Philonotis revoluta* BOSCH. et LAC. x 300
4-6 : *Philonotis turneriana* (SCHWAEGR.) MITT. x 300
a : Cross sections, b : Longitudinal sections


3a
2b
2a
1a
1b







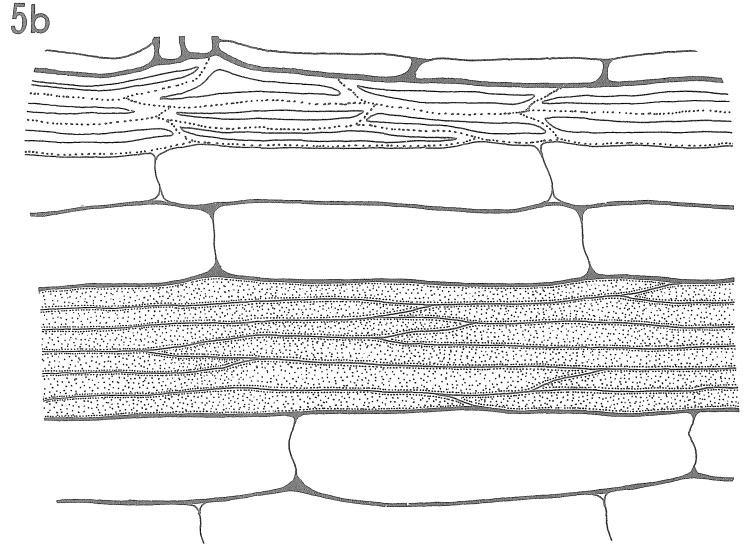
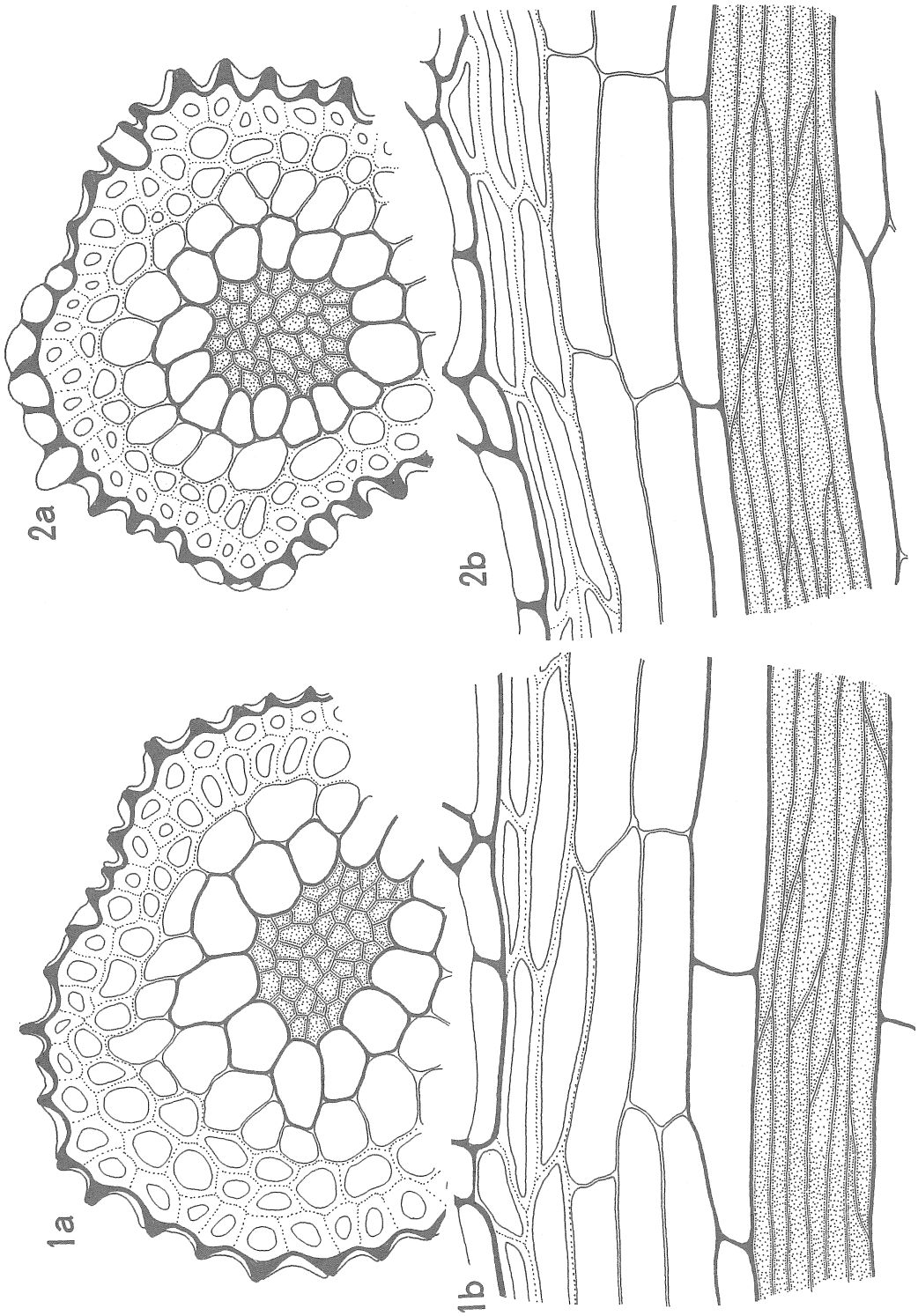


Plate III Cross and longitudinal sections of the stem
1-3 : *Philonotis falcata* MITT. x 400
4-5 : *Philonotis socia* MITT. x 300
a : Cross sections, b : Longitudinal sections


2a
2b
1a
1b

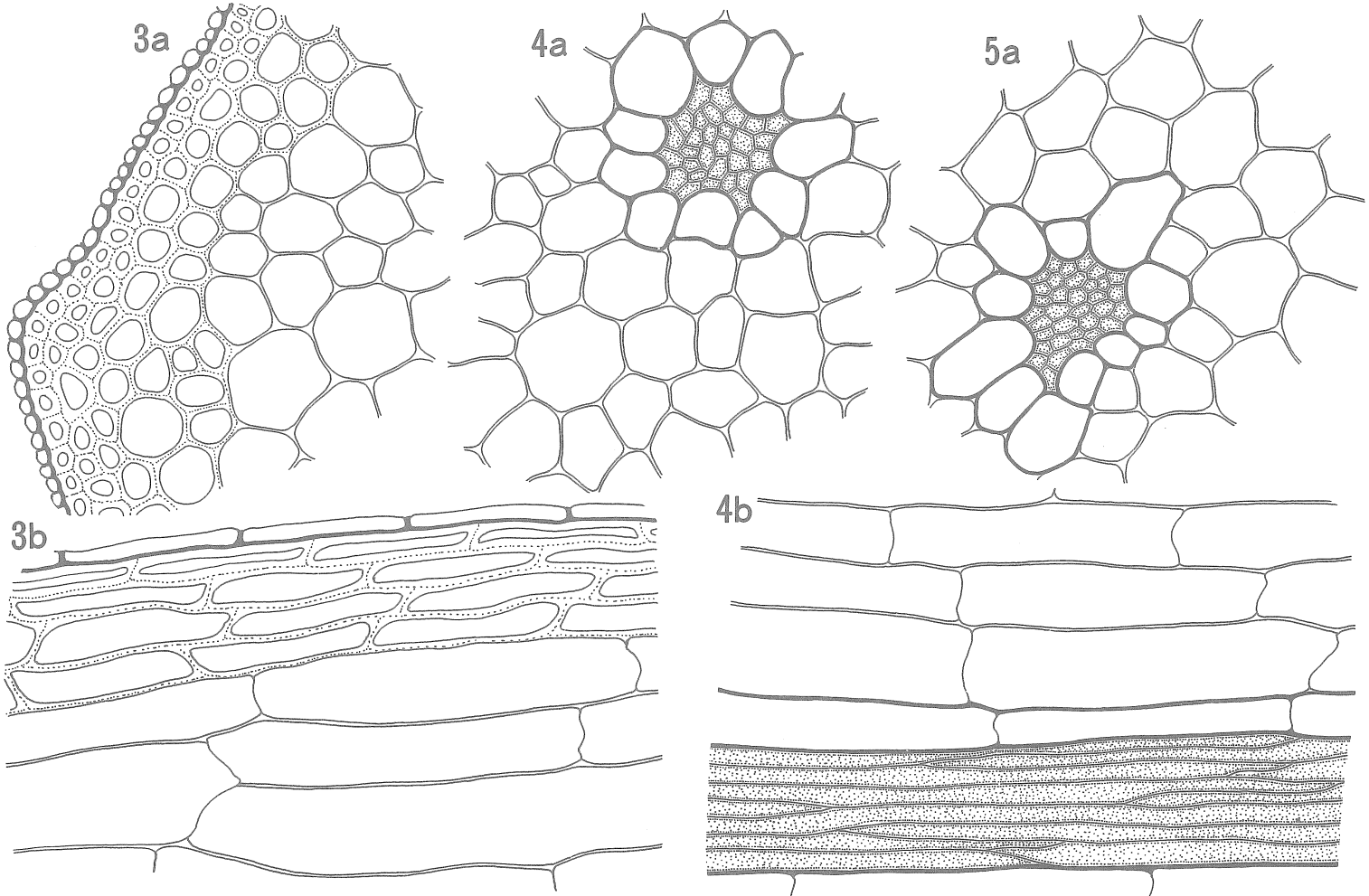
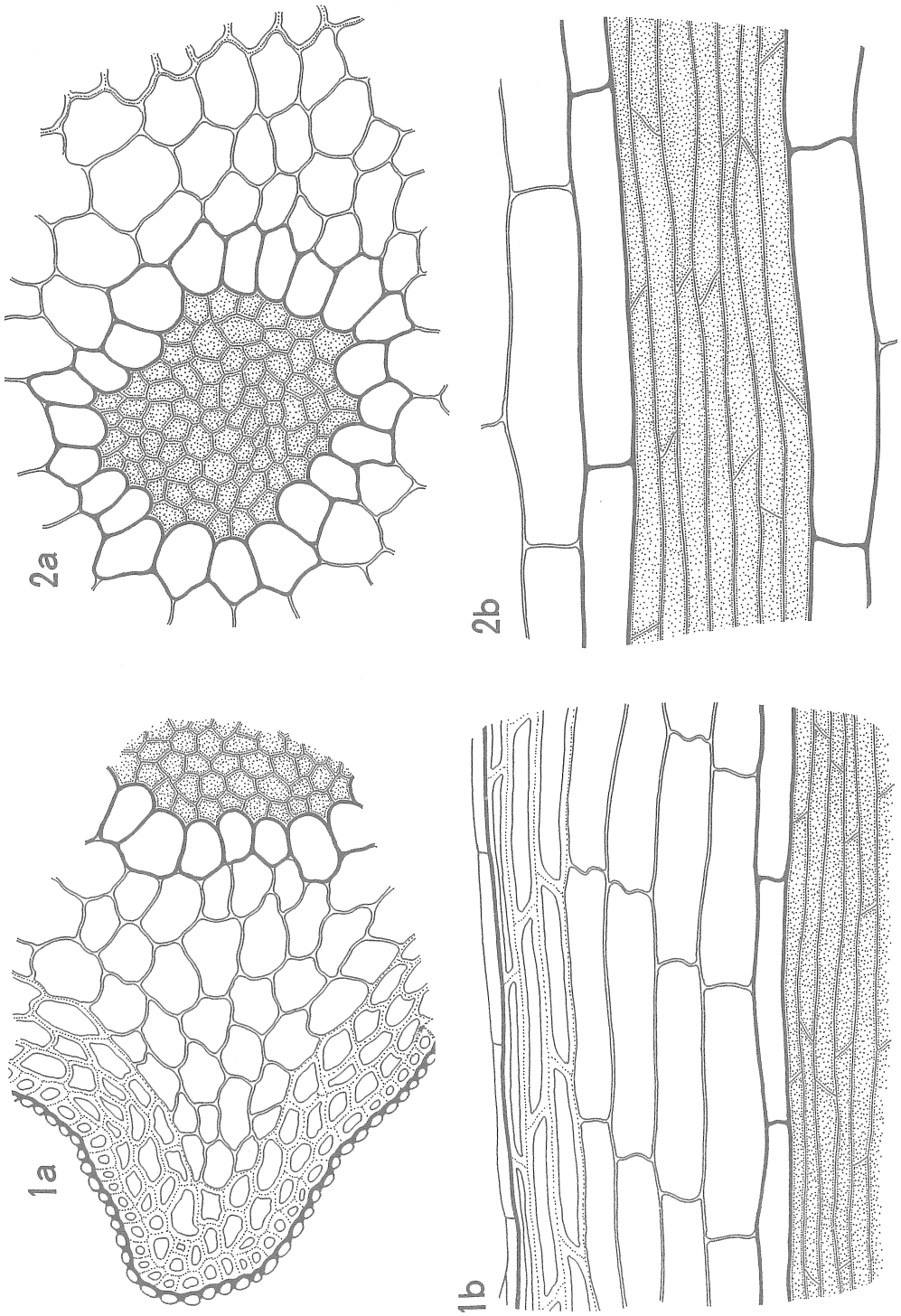


Plate IV Cross and longitudinal sections of the stem
1-2 : *Philonotis thwaitesii* MITT. x 400
3-5 : *Bartramia pomiformis* HEDW. var. *elongata* TURN. x 400
a : Cross sections, b : Longitudinal sections


2a
2b
1a
1b

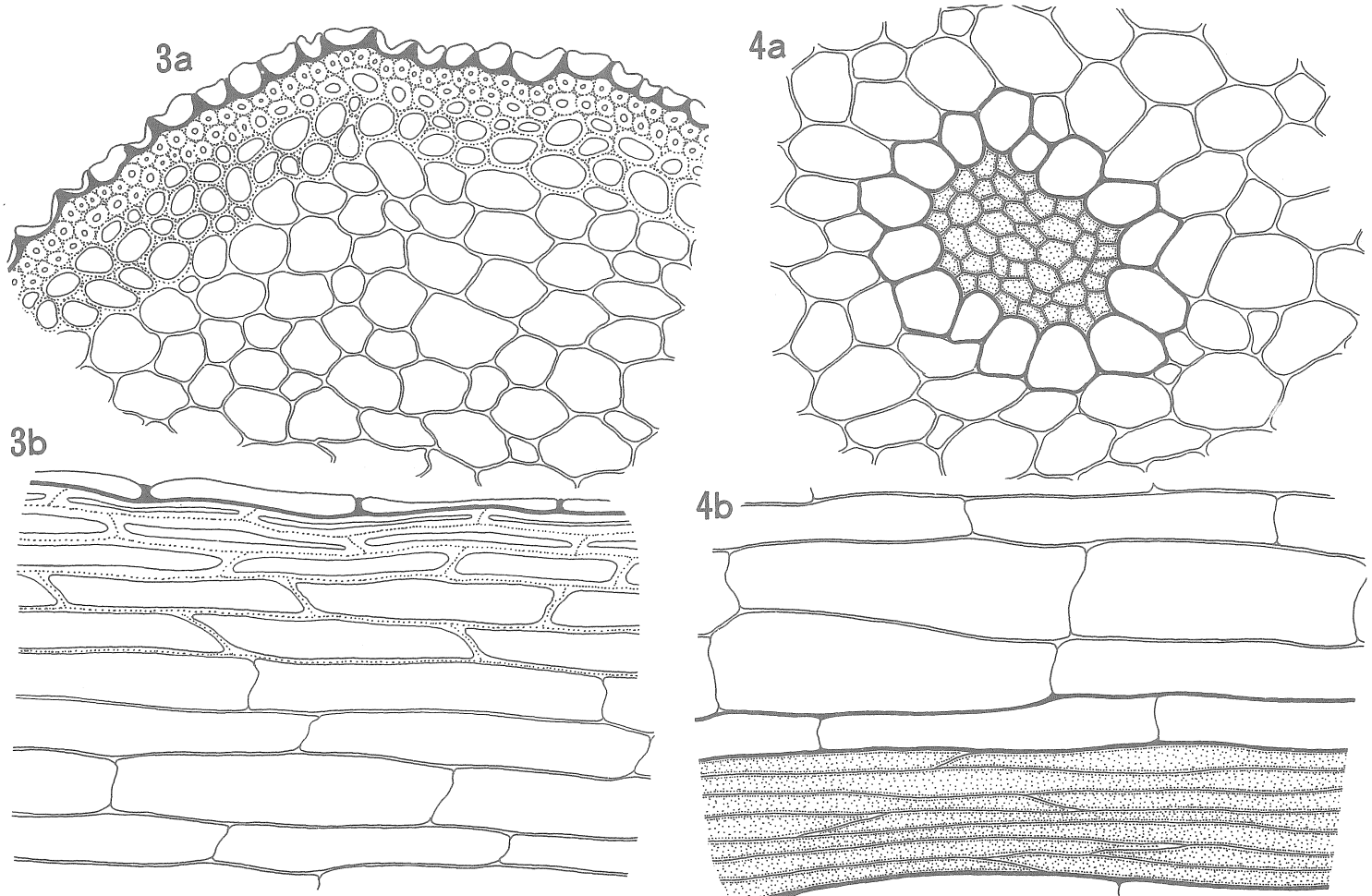


Plate V Cross and longitudinal sections of the stem
1-2 : *Bartramia pomiformis* HEDW. x 300
3-4 : *Breutelia arundinifolia* (DUB.) FL. x 300
a : Cross sections, b : Longitudinal sections